Player Tracker - A Tool to Analyze Sport Players using RFID

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***Abstract*— A work in progress of a tool designed to help sports coaches to analyze their players using an RFID technology connected to a 3-layer software is described in this paper. A few ranging techniques available in conventional RFID systems were studied to best fit this application scenario. Together with the RFID equipments, there is a 3-layer system managing all the data. The software bottom layer is responsible for the low-level communication between the software and the hardware. The middle layer is the system engine where all the calculation is performed. Finally, the top layer is the software part responsible for showing reports and the player analyzed. The system has 2 tracking modes, one for 2D player location in the field, and a 3D mode to capture players' movement in small area sports. It has 2 report modes also, one for real-time report displaying each player's actual location in the field; and the other to present reports with statistics of the player such as distance covered, a heat map of the field showing where the player is at a time interval and number of sprints.**

Keywords- Pervasive Computing; RFID; RSSI; RTLS; Smart Environment; Sports; TDOA;

I. Introduction

Sport practices were always present in humankind since its beginning. Evidences have been found of this habit in ancient known civilizations, such as the Greeks, Egypt and Aztec. Over time, sports were professionalized and demand more and more of the athlete's body, increasing competitiveness. A proof of this fact is the time difference between the first and second place in individual sports, as compared to what it was in the beginning of the XX century and what it is nowadays. Previously, the time difference was dozens of seconds, and even minutes in some sports. But now, this difference is in the order of tenths of seconds, and several times a tie occurred in the swimming competition in the Beijing Olympic Games. Hence, every single detail is considered aiming to increase the athlete's time in some tenths of seconds on his/her final time.

However, even with all athlete endeavors, every person will always be restricted by the physical limitation of the human body. Thus, the athlete should not do only his physical training; he should improve the movement execution technique and the sport practices strategy. This is where the coach and the trainer are fundamental to the athlete's training. The trainer analyzes the athlete's movements and instructs alterations in his/her movements' execution so as to reach the maximum performance of the body. In team sports, the coach is responsible for analyzing and for correcting the players' positioning inside the field, suggesting offensive and defensive strategies and choosing the best player for each position in the team. Hence, any tool that can help the trainer and the coach will help the athlete to reach the best results in the practiced sport. Thinking of this, a player tracking system using Radio-Frequency Identification Technology (RFID) was projected here. This system was designed to meet two specific demands: to help trainers to analyze the athlete's movements in a simpler way than the actual camera assistant image capture technique, here called 3D tracking; and supply a tool for tactically analyzing team sports, named 2D tracking.

The paper is divided into 7 sections: First the introduction and later the related works. Section 3 presents the system architecture and sections 4 and 5 present the detailed information about two layers of the system. In section 6, some evaluation about the system is presented and future works are proposed in section 7.

II. Related Works

During the research conducted, one paper was found describing a system for football real-time analysis using a very specific technology to do the position measurement [1]. The authors defined a Football Interaction and Process Model – FIPM – that extracts the events of the game based only on the position of the players and the ball. This model allows measuring and predicting some events such as goal opportunities, for instance, based on the angle of the player in relation to the goal and the position of the defender. Thus, at the end of the game it is possible to extract reports measuring how many goal opportunities were lost by each player. Yet this system demands precise and complex acquisition equipment. The equipment chosen was one that had not been released in

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the market neither fully tested at the time of the publication of the paper, so the system was only tested using the 2003 RoboCup Simulated League, which consist of simulated match data. In this Player Tracker project, the focus is the use of standard low-cost commercial RFID systems to reduce the cost with an acceptable precision and refresh rate. These systems, compared to the one expected to be used in Beetz paper, have some disadvantages such as small precision (1~2 meters against 5~8 cm) and low report frequency (1 hertz against 700 Hz for players and 2 kHz for the ball). Yet these RFID systems demand a small time for installation, calibration and startup, allowing the system to be installed a few minutes before the beginning of the game and uninstalled after the match is over. On the software side, the models and the algorithms were developed only considering football. These models are very complete, allowing the software to detect goal opportunities, but these models cannot be used for sports other then football. The Player Tracker here described can be used in any field sports to analyze either teams' movements or individual sports viewing the player's biomechanics.

When compared to market available solutions, there is a solution that allows performing tactical analyses using video cameras called TeamPro [2]. The cameras capture the images and the software allows the user to tag events, providing an easy and fast event search tool. For each event, the system generates a short video clip, and allows it to be broadcast in the internet or just be watched as a replay. The real-time tools available in this system are a quick replays generator with a predefined past time and a real-time events tagging tool. These systems based on video camera are very easy to setup in the field and can be easily used in any sport modality, but they lack automated tools to track the player and to provide real-time reports about the match and each player.

III. System Architecture

The system is organized as a three-tier layered architecture with the system artifacts organized as follows: the RFID hardware communication proceeding at the very bottom layer of the system, the software engines modulating at the middle tier, and the presentation and reporting functionality displaying at the top layer of the system through the system-user interface. *RFID tracking* is the name of the bottom layer and performs the actual outdoors calculations on the players moving in the field. The *software processing engines* layer, the middle layer, uses the acquired measurements from the *RFID tracking* layer in order to perform calculations to obtain positions of the players and statistics. The *presentation and reporting* layer is at the top of the architecture and uses such calculations in order to plot the graphics at the system-user interface. As can be seen, the system is structurally neat with separating processing over the three layers. The system three-tier layered architecture model is schematically presented in Fig. 1.

The communication between the readers and the software engine is made though a RFID middleware present in the *RFID tracking* layer. This layer communicates with many different RFID reader protocols with different frequencies and different measurement techniques. In the case of the 3D tracking, this layer will provide information packets with all the tags read by the reader with their respective range few times per second, depending of the number of tags. For the 2D tracking, the middleware will provide the ranging information of all tags every reading that happens in a one-second interval.

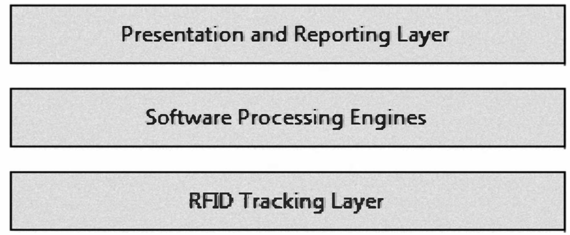

Figure 1. Player Tracker system architecture.

RFID tags can be active or passive. The active ones are self fed by an internal battery and the passive ones are fed with the energy from the electromagnetic waves sent by the reader. Some RFID readers provide information on the distance or the position between the reader and the tag. The data can be based on few different techniques, and the most used are: Received Signal Strength Indication – RSSI, Time Difference of Arrival – TDOA, Angle of Arrival – AOA, Time of Flight –TOF. RSSI is based on the strength of the signal received by the reader. TDOA calculates the distance between the reader and the tag based on the time difference of the signal sent by the tag and received by the reader. AOA technique measures the angle where the signal of the tag arrives, normally using special direction sensitive antennas. With two or more readers knowing the angle where the signal arrives, it is only a matter of plotting a line leaving the readers in the received angles to find the position. TOF technique is similar to the TDOA; the difference lies in the fact that the signal is sent by the readers and the time measurement is made by the tag [3].

Since the Player Tracker can be used for team games analyzing the players' movement or it can be used in individual sports to analyze the biomechanics and the movements of the player, two different RFID technologies were used. In the field games, where the 2D analysis is enough, a cheap commercial dual frequency active RFID technology with RSSI indication feature was used. For the 3D analyses necessary in the individual sports, a passive UHF RFID called RFID-Radar was chosen due to its precision and high reading speed [4].

IV. Middle Layer – Software Engines

The software operating on the results and measurements obtained by the *RFID tracking* layer is placed on the middle layer. This layer consists of two calculation engines: the 2D engine for modeling the field view and the 3D engine for modeling players' movements and articulations. Besides the calculations acquired by the RFID bottom layer, the software engines will perform some mathematical calculations specific to them in order to support the graphical modulation itself.

The purpose of the 3D engine is to perform calculations on the positions of each body articulation in order to provide modulation for the microscopic view of a player's body movements. For the purposes of this engine, the passive RFID tags is a means to acquire the measurements of each body part position through the mix of the AOA and TDOA technique illustrated in the previous part. Knowing the position of each

tag attached to a body part, it allows the modeling of the body on a 3D Cartesian plane. The exact display of such modeling and 2D modeling will be made clearer as the top layer is discussed in the next section.

The 2D engine accounts for modeling the overview of the playground level. It models the distribution of players over the field according to each player's exact position, the relative positions between players, the relative movements of players, the movement pattern of each player, and time spent by each player in each area of the field. The exact player's position in the field is acquired by the use of RFID readers placed on the field borders. The readers will conduct continuous triangulation calculation on each player in order to track the players continuously as they move through the field.

Applying the same technique on each player using RF readers, it is possible to locate each player's exact position in the field. Besides the triangulation provided by the RF readers, the fact that the size of the field is known can be used in determining the position by splitting the field into a predefined scale. Part of the calculations feature of the 2D engine is to calculate the relative positions among players. The exact positions acquired by triangulations are used at this level of calculation. For example, knowing the exact positions of two players, it is possible to draw a straight line between those two players. The length of that straight line is the relative position of those two players. The length of the line is calculated by the straight line equation.

In order to track the relative movements of players dynamically, an algorithm here called Stretching Shrinking Graph – SSG was adopted. The name of the algorithm refers to the stretching of the graph as the players move further away or the shrinking of the graph as the players move close to the straight lines stretching or shrinking, respectively. The monitoring of the movement pattern of a player has been performed by storing successive exact positions; then, connecting those points with straight lines. This will display the movement pattern stamped by a vector showing the direction of the movement.

The last calculation made is the time spent in each area of the field. The players' movements in the playground are tracked using multithreading technique. Each thread represents the different areas of the field, such as defense, center and attack areas. The system will start a parallel thread which remains active as long as the player is present in one area; once the player leaves that area, the thread will become inactive or sleep; then, it reports how much time the thread remained active. Such time of thread activeness in the system is used as the time spent by that player in a specific area.

V. Top Layer – Presentation and Reporting

At this top layer, the calculations made on the middle-tier layer are used in plotting the graph at the user interface terminal while displaying some statistical reports. The field is represented as a two-dimensional grid with each cell size predefined according to the RFID reader precision. As noted in the previous section, the overall size of the grid is known with the fact that any sport field size is fixed and pre-known. This fact is used when dividing the playground into a grid, as well.

A. *Presentation*

The presentation of the system consists of the presentation of the 2D field and the presentation of the 3D plane. The 2D field rendering plots the players' exact position in a grid of the field and connects each player with a straight line. After that, it shows the relative positions by drawing the straight lines length using the 2-point intersection on the x-axis and the 2-point intersection on the y-axis. Fig. 3 shows the 2D field representation.

In the 3D plane rendering, the positions of body parts are to be depicted on a 3D Cartesian plane for graphic modulation. With each node presenting the specific body part, each movement of a part is displayed in the 3D plane using the calculations acquired by the RFID. The visualization is made by a wireframe diagram, seen in Fig. 3. Each node of the diagram represents a tag attached to a part of the body. The wires linking each node are placed automatically by the system based on a tag linking configuration loaded previously.

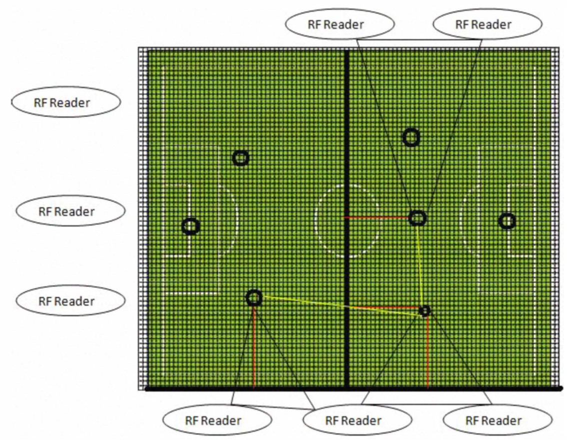

Figure 2. 2D relative positions presentation: The nodes representing each player's position using the RFID triangulation calculations are represented by the black circles; the 2-point intersections on the x-axis and y-axis are represented by the red lines and the relative positions are the connecting straight lines represented by the yellow lines.

B. *Reporting*

The field grid can be sub-divided according to the field playground different playing areas, such as the defense area for instance. Each divided area has a color band so that it can be visually distinguishable from the other areas. The size of the area is predefined in the system depending on the sport. Using the multithreaded technique discussed in the previous section, it is possible to track the time spent by each player according to the predefined areas. The statistics acquired in that step is displayed as a table accordingly showing the percentage of time in each part of the field. The crossing of this report with the positioning history allows a heat map report, seen in Fig. 4, showing which parts of the field the player spent more time in. Other reports generated by player are the total distance travelled, number of sprints, maximum speed, etc.

VI. Evaluation

The system here described was neither fully implemented nor tested in a true sports competition. The first layer is almost ready, the second is well advanced for the 2D calculations, and

third layer is in a very initial development. All the data used to test the system are based on the RoboCup data or captured by the RFID readers tracking only one person. However, the proposed system can provide analytical and accurate tracking data for sports players at the field level. RFID provides a powerful technique for acquiring basic position calculations, which aids the acting software to conduct some mathematical calculations to pinpoint each player's relative positions and movements. The system proposes an innovative, flexible, and state-of-the-art analytical and graphical depiction for any team or individual sport modality.

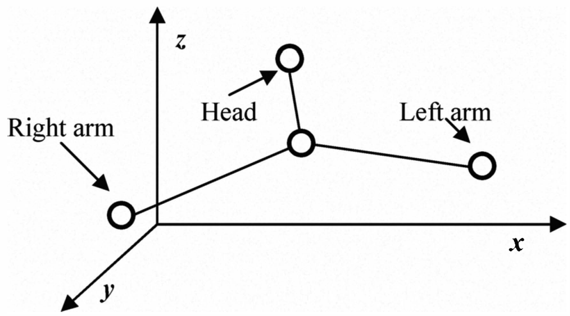

Figure 3. 3D body movements presentation: The 3D wire diagram of a athelet body with 4 RFID tags, one on each arm, one in the head and other in the chest.

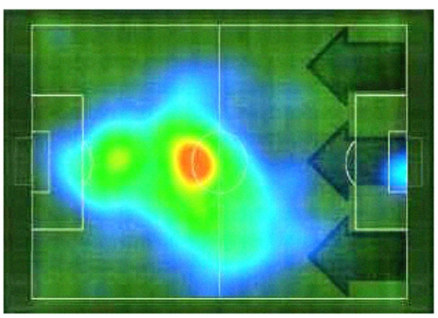

Figure 4. Heat map of a player movement in the field

The mathematical calculations involved are vectors manipulation or geometry calculation. They are considered simple in terms of processing capability, but since some sports have a large number of players, the software is being developed to run in Cell BE processor based equipment, which supports SIMD instructions. The use of such processor avoids slowness in the system by the computation, even if the RFID equipment used is replaced by a new one with the update time faster than the actual ones. The CellSs framework has been used to develop the system, since it allows a quick development of software for heterogeneous multi-core processors and provide useful tracing tools [5]. Developing the software based on the Cell BE architecture allows the system to be executed by a Playstation 3. This device has a cheaper cost than that of a standard PC with similar computational capabilities, and allows the Player Tracker solution to be used as a black box solution.

Many challenges were faced during the development of this system. The first was the choice of the RFID technologies and the ranging techniques available among many. Another challenge was the analysis of the data and reports presentation in such a way that it can be useful for both coach and sport trainer. However, the most difficult challenge during this development was undoubtedly the integration of both 2D and 3D engines. Although the analysis is based on the same principle of measuring the distance from the tags to the reader, the design of a database capable of extracting flexible reports for both engines demanded a lot of project time.

VII. Future Plans

As a next step, the software development will be finalized, and tested in a full RoboCup match data. Later, one field sport and one close contact sport will be chosen to acquire real data and to test the engines. Since football is the most played game in the world, the first trial of the 2D engine is more likely to be made in a football match. For the 3D engine, due to its short range, it is necessary to choose a close contact sport. A box arena is small enough to allow the installation of many readers and validate its functionality. Other sports in which the system can be tested are the track and field modalities, such as long jump and hammer throw, for instance, in which the athlete performs movements in a very small area, easily covered by the passive RFID readers. Later, RFID readers with faster position refresh rate and small reading range will be used to increase the system precision when necessary, like small fields sports.

Finally, a last future plan is a new presentation option that allows the coach to reconstruct the match in a 3D engine with a free camera position. It will allow the trainer to see and to show to the other players exactly what each player saw in any minute of the game, as a first-person camera. Other viewing option is to watch the game from any point of the field, allowing the coach or football players head-hunters to watch the game like they were in the middle of the field, next to any specific player.

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